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SEMICONDUCTOR LASER DEVICE

Inventor:	Oyashi Anayama Fujitsu, Ltd. 1015 Kamiodanaka, Nakahara-ku, Kawasaki-shi
Applicant:	000005223 Fujitsu, Ltd. 1015 Kamiodanaka, Nakahara-ku, Kawasaki-shi
Agent:	Teiichi Igeta, patent attorney

[There are no amendments to this patent.]

Abstract

Objective

The present invention pertains to a semiconductor laser device for optical communication. The present invention provides a semiconductor laser element that can be used as the light source for commercial optical communication applications.

Constitution

Semiconductor laser (1) comprises substrate (2) made of GaAs, and active layer (3) made of GaInAsN.

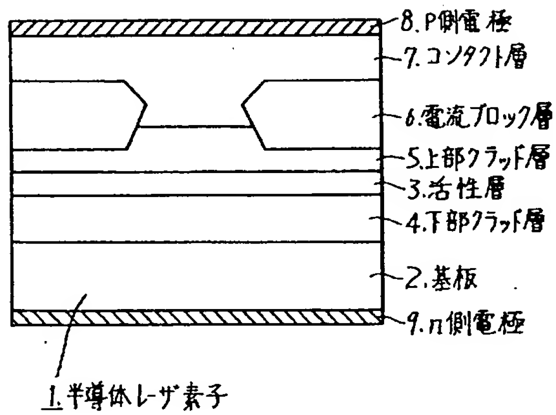

Diagram illustrating the principal of the present invention.

Key:

1	Semiconductor laser element
2	Substrate
3	Active layer
4	Lower cladding layer
5	Upper cladding layer
6	Current block layer
7	Contact layer
8	p-side electrode
9	n-side electrode

<u>Claims</u>

1. Semiconductor laser device characterized by the fact that substrate (2) is made of GaAs, and active layer (3) is made of GaInAsN.

2. The semiconductor laser device described in Claim 1, characterized by the fact that the proportion of N in AsN of GaInAsN of said active layer (3) is 0.5% or higher.

Detailed explanation of the invention

[0001]

Industrial application field

The present invention pertains to a method for manufacturing semiconductor laser devices for optical communication. The data communication rate for optical communication using optical fibers continues to increase, and optical fibers are now widely used as trunk networks. Also, with improvements in digital information processing technology, optical fibers are expected to be used in the next-generation optical communication networks at the level of individual users.

[0002]

The present invention provides a semiconductor laser element that can be used as the light source for commercial optical communication applications.

[0003]

Prior art

The conventional semiconductor laser element for optical communication is made of a InGaAsP-based material with InP as the substrate. The laser emits radiation at a wavelength of 1.55 μm or 1.3 μm.

[0004]

Conventional devices are made this way because lasers made of InGaAsP on an InP substrate have a very long lifetime, and optical loss and wavelength dispersion in the fused silica glass fibers are minimized. Because this optical communication network is widely used in commercial applications, it is necessary to operate at a wavelength with low optical loss (1.3 μm), and there should be little degradation in the characteristics at high temperature (high characteristic temperature).

[0005]

However, a high characteristic temperature is hard to realize using a conventional InGaAsP-based material with an InP substrate. Consequently, tests have been done on high characteristic temperature for strained GaInAs on a GaAs substrate.

[0006]

Problems to be solved by the invention

A longer wavelength for strained GaInAs on a GaAs substrate is realized by increasing the amount of compressive strain. However, for this series of materials, the limit strain is about 2%. Consequently, the limiting wavelength that is free of dislocations is about 1.1 μm, and it is hard to increase the wavelength to the target wavelength of 1.3 μm.

[0007]

When a compound crystal of a material having a longer wavelength is used as the active layer, the band gap can be reduced. However, for InP, InAs, GaSb, InSb, etc., which have band gaps smaller than that of GaAs, the lattice constants are larger than that of GaAs. Consequently, if the band gap is reduced by using a compound crystal of these materials, the compressive strain is definitely increased.

[0008]

Consequently, there is demand for a material that can reduce the band gap through the use of compound crystals, but that does not result in an increase in strain. The purpose of the present invention is to provide a semiconductor laser element that can be used as a light source for commercial applications.

[0009]

Means to solve the problems

Figure 1 is a diagram illustrating the principle of the present invention. In this figure, (1) represents a semiconductor laser element; (2) represents a compound semiconductor substrate; (3) represents an active layer; (4) represents a lower cladding layer; (5) represents an upper cladding layer; (6) represents a current block layer; (7) represents a contact layer; (8) represents p-side electrode; and (9) represents n-side electrode.

[0010]

According to the present invention, GaAs is used as compound semiconductor substrate (2), and, for the strained InGaAs layer as active layer (3), nitrogen is introduced so as to reduce the band gap without increasing the compressive strain.

[0011]

The purpose of the present invention is realized by a semiconductor laser device shown in Figure 1, characterized by the following facts: substrate (2) of semiconductor laser element (1) is

made of GaAs; active layer (3) is made of GaInAsN; and the proportion of N in AsN of GaInAsN as active layer (3) is 0.5% or higher.

[0012]

Operation

Examples of nitrogen-based compound crystals include AlN, GaN, InN, etc. However, all of them have much larger band gaps than that of GaAs, and they all have small inter-atomic bond lengths.

[0013]

Consequently, when a compound crystal is formed from these materials and GaAs and InAs, tensile strain is applied on the GaAs substrate. The band gap is believed to be larger than those of GaAs and InAs. However, according to a recent report published at a symposium (Dai 12kai Konsho Erekutoronikusu Shimpojiumu Ronbunshu [Proceedings of 12th Symposium of Compound Crystal Electronics], IV-10 (p. 337), IV-11 (p. 341), the use of GaAsN and GaPN produces a smaller band gap because of the introduction of N.

[0014]

It is believed that this is because the size of the N atoms is significantly different from those of As atoms, etc., so that bowing of the compound crystal becomes very large. Consequently, for the compound crystal of InGaAs and N, when tensile strain is applied, it is possible to relax the compressive strain and to reduce the band gap. This is an advantage.

[0015]

Consequently, by means of introducing N into the crystal, for strained GaInAsN, the compressive strain can be suppressed to less than 2%, and it is possible to obtain a wavelength of 1.3 μm.

[0016]

Application examples

Figure 2 is a schematic cross-sectional view illustrating the steps of an application example of the present invention. In this figure, (10) represents a semiconductor laser element; (11) represents n-type GaAs substrate; (12) represents Si-doped GaAs buffer layer; (13) represents n-side Si-doped GaInAsP cladding layer; (14) represents first n-side guide layer of undoped GaInAsP; (15) represents second n-side guide layer of undoped GaAs; (16) represents undoped GaInAsN active layer; (17) represents second p-side guide layer of undoped GaAs; (18)

represents first p-side guide layer of undoped GaInAsP; (19) represents p-side cladding layer of Zn-doped GaInP; (20) represents Si-doped GaAs contact layer; (21) represents SiO_2 film; (22) represents mesa stripe structure; (23) represents Si-doped current block layer; (24) represents Zn-doped GaAs contact layer; (25) represents p-side electrode; and (26) represents n-side electrode.

[0017]

Growth of the various layers of the compound semiconductor on the compound semiconductor substrate can all be carried out using the MOVPE method. For Ga and In, organic metals can be used; and for As and P, arsine, phosphine, and organic group-V, and other materials can be used.

[0018]

Figure 2 is a cross-sectional view illustrating schematically the steps of the manufacturing process of the semiconductor laser having the constitution of the present invention. In the following, the manufacturing process of the semiconductor laser in the present invention will be explained with reference to Figure 2.

[0019]

First of all, using the MOVPE method, the following layers were laminated consecutively on n-type GaAs substrate (11): Si-doped GaAs buffer layer (12) with a thickness of 1 μm; n-side cladding layer (13) of Si-doped GaInP with a thickness of 2 μm; first n-side guide layer (14) of undoped GaInAsP with a thickness of 0.2 μm; second n-side guide layer (15) of undoped GaAs with a thickness of 0.1 μm; undoped GaInAsN active layer (16) with a thickness of 0.1 μm (proportion of Ga is 0.74; proportion of N is 0.01; strain 1.9%; PL wavelength 1.3 μm); second p-side guide layer (17) of undoped GaAs with a thickness of 0.1 μm; first p-side guide layer (18) of undoped GaInAsP with a thickness of 0.2 μm; p-side cladding layer (19) of Zn-doped GaInP with a thickness of 0.1 μm; and Si-doped GaAs contact layer (20) with a thickness of 1 μm.

[0020]

The growth temperature was 650°C, and dimethyl hydrazine was used as the N-material. Figures 2-4 [sic; only 2 figures in original] illustrate Application Examples 2 and 3 of the present invention. Then, on contact layer (20), with SiO_2 film (21) used as the mask, upper cladding layer (19) was etched to form mesa stripe structure (22).

[0021]

Then, using the MOVPE method, Si-doped GaAs current block layer (23) was selectively grown, the mask of SiO_2 film (21) was removed, and Zn-doped GaAs contact layer (24) was grown. Finally, p-side electrode (25) and n-side electrode (26) were formed. Then it was cut at right angle to the stripe, and with the p side down, it was bonded to a heat sink.

[0022]

In this way, semiconductor laser element (10) of the present invention was formed.

[0023]

Effects of the invention

As explained above, according to the present invention, by introducing N into the strained GaInAs of the growth layer, it is possible to form a semiconductor laser element on a GaAs substrate that is free of dislocations and that emits radiation at a wavelength of 1.3 μm. Compared with the laser formed on InP substrate, a higher characteristic temperature can be realized in the present invention.

Brief description of the figures

Figure 1 is a diagram illustrating the principle of the present invention.

Figure 2 is a cross-sectional view illustrating schematically the steps in an application example of the present invention.

Explanation of symbols

1	Semiconductor laser element
2	Compound semiconductor substrate
3	Active layer
4	Lower cladding layer
5	Upper cladding layer
6	Current block layer
7	Contact layer
8	p-side electrode
9	n-side electrode
11	n-type GaAs substrate
12	Si-doped GaAs buffer layer
13	n-side cladding layer of Si-doped GaInP
14	First n-side guide layer of GaInAsP

15 Second p-side guide layer of GaAs
16 GaInAsN active layer
17 Second n-side guide layer of GaAs
18 First p-side guide layer of GaInAsP
19 p-side cladding layer of Zn-doped GaInP
20 Si-doped GaAs contact layer
21 SiO_2 film
22 Mesa stripe structure
23 Si-doped current block layer
24 Zn-doped GaAs contact layer
25 p-side electrode
26 n-side electrode

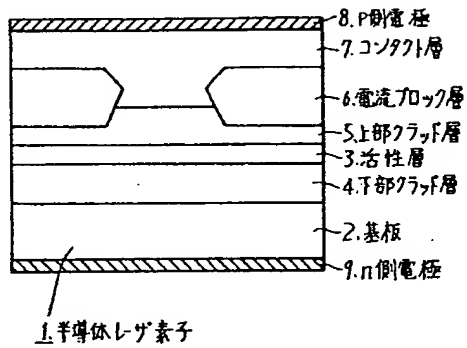

Figure 1. Diagram illustrating the principal of the present invention.

Key:
1 Semiconductor laser element
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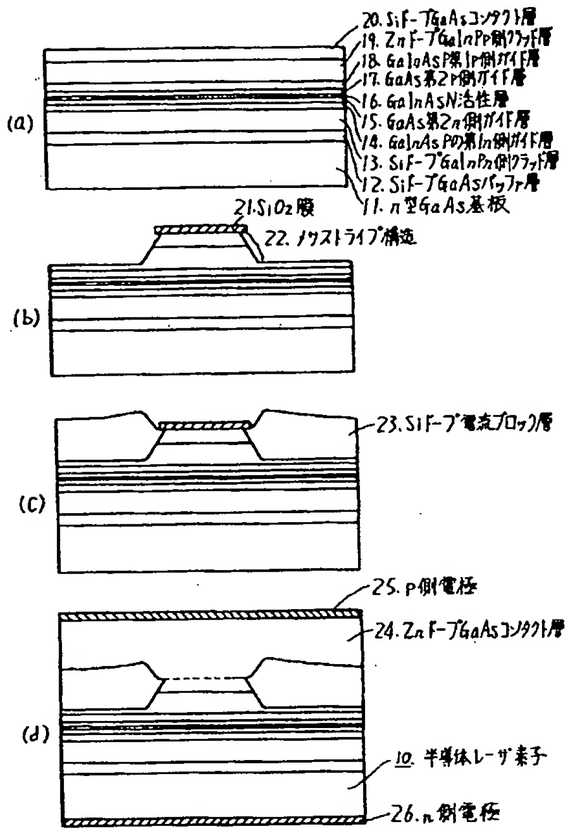

Figure 2. Cross-sectional view illustrating schematically the steps in an application example of the present invention.

Key:		
	10	Semiconductor laser element
	11	n-type GaAs substrate
	12	Si-doped GaAs buffer layer
	13	n-side cladding layer of Si-doped GaInP
	14	First n-side guide layer of GaInAsP
	15	Second p-side guide layer of GaAs
	16	GaInAsN active layer
	17	Second p-side guide layer of GaAs
	18	First p-side guide layer of GaInAsP
	19	p-side cladding layer of Zn-doped GaInP
	20	Si-doped GaAs contact layer
	21	SiO_2 film
	22	Mesa stripe structure
	23	Si-doped current block layer
	24	Zn-doped GaAs contact layer
	25	p-side electrode
	26	n-side electrode